



Evidence of Climate Change in Minnesota: What our measurements show

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For St Paul Climate Action Planning

February 27, 2017

Top Ten Warmest Autumns Statewide for Minnesota

	Year	Temp	Sep-Nov
1.	1963	49.7	
	2016	49.7 (tie)	
3.	2015	49.5	
4.	1931	48.7	
5.	2004	47.6	
6.	1953	47.5	
	2001	47.5	
8.	1994	47.3	
	1998	47.3	
10.	1922	47.2	
	2005	47.2	



**Kandiyohi County Fairgrounds
after flash flood Aug 10-11, 2016**

2015-16 Avg Dept. from
Month Temp 1981-2010 Normal

Twin Cities Monthly Temps

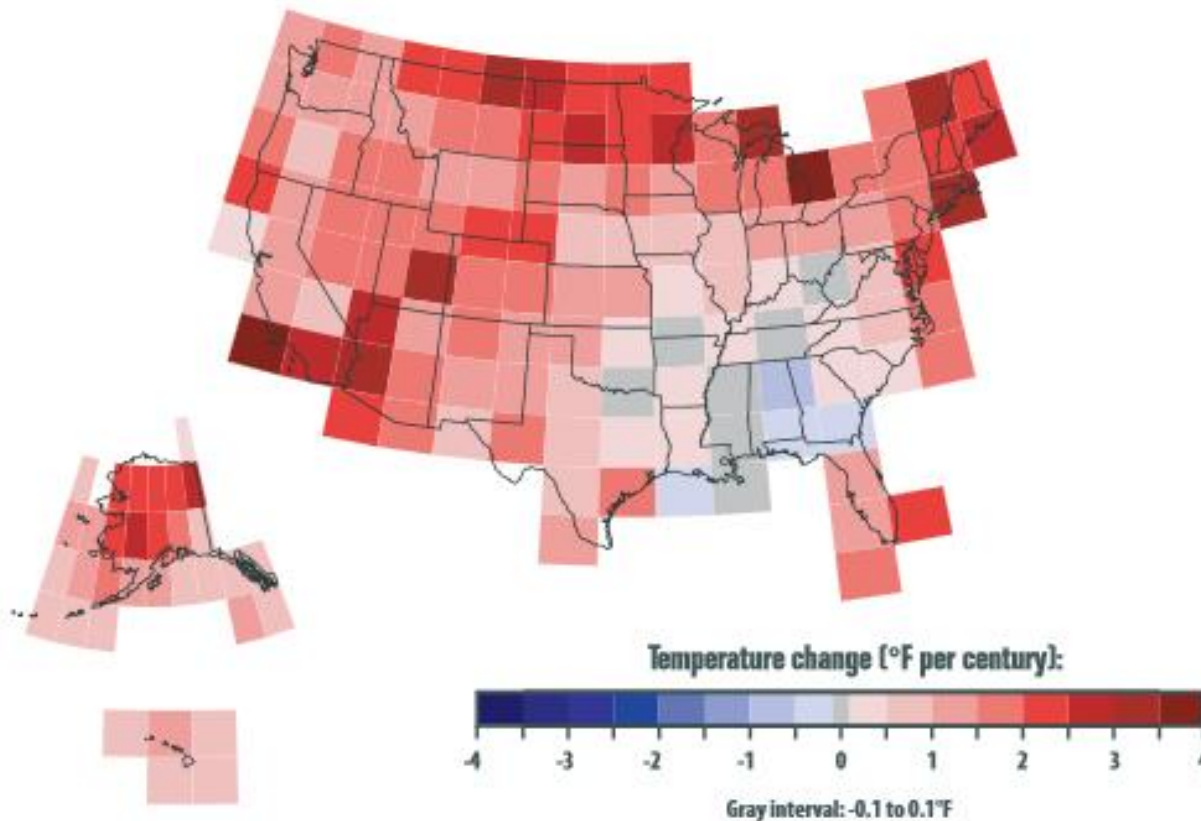
September	67.9	+ 5.9
October	52.1	+ 3.2
November	44.1	+10.4
December	30.2	+10.5
January	17.6	+ 2.0
February	24.9	+ 4.0
March	41.3	+ 8.5
April	48.1	+ 0.6
May	61.3	+ 2.2
June	71.3	+ 2.4
July	75.2	+ 1.4
August	73.4	+ 2.2
September	66.1	+ 4.1
October	52.9	+ 4.0
November	44.1	+10.4
December	20.9	+ 1.2

Jan'17 20.7 + 5.1*projected
17 consecutive months warmer than normal

Station	2016 Record Precip. Amount	Previous Record (year)
Waseca	56.24"	50.46" (1991)
St. James	52.55"	42.72" (2010)
Harmony*	49.36"	47.41" (1983)
Austin	48.35"	46.01" (1993)
Theilman	48.33"	47.20" (2010)
Minnesota City Dam	45.73"	44.29" (1968)
Winona Dam	43.57"	43.27" (1991)
Twin Cities	40.32"	40.15" (1911)

Figure 3. Rate of Temperature Change in the United States, 1901–2008

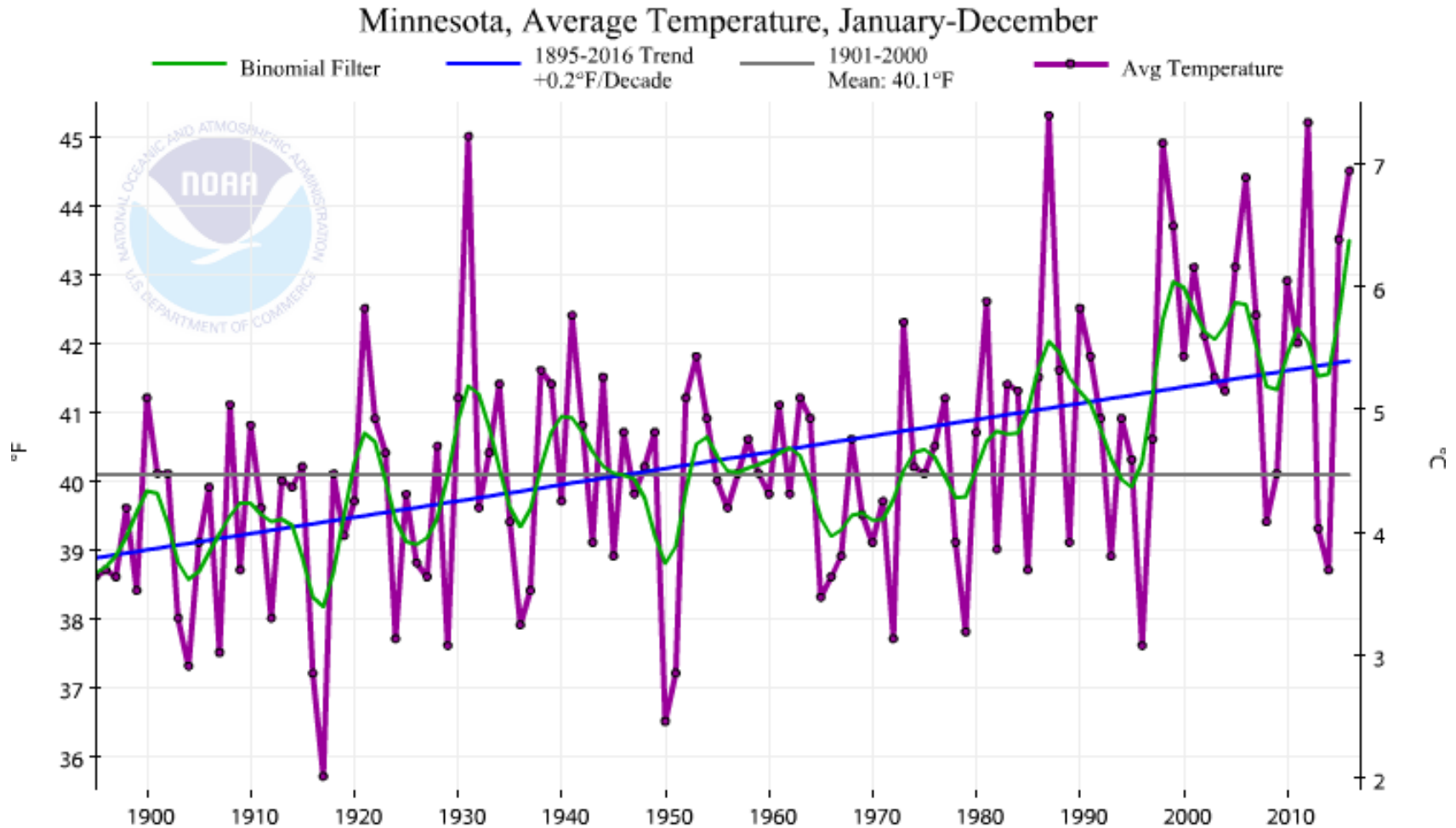
This figure shows how average air temperatures have changed in different parts of the United States since the early 20th century (since 1901 for the lower 48 states, 1905 for Hawaii, and 1918 for Alaska).



Data source: NOAA, 2009*

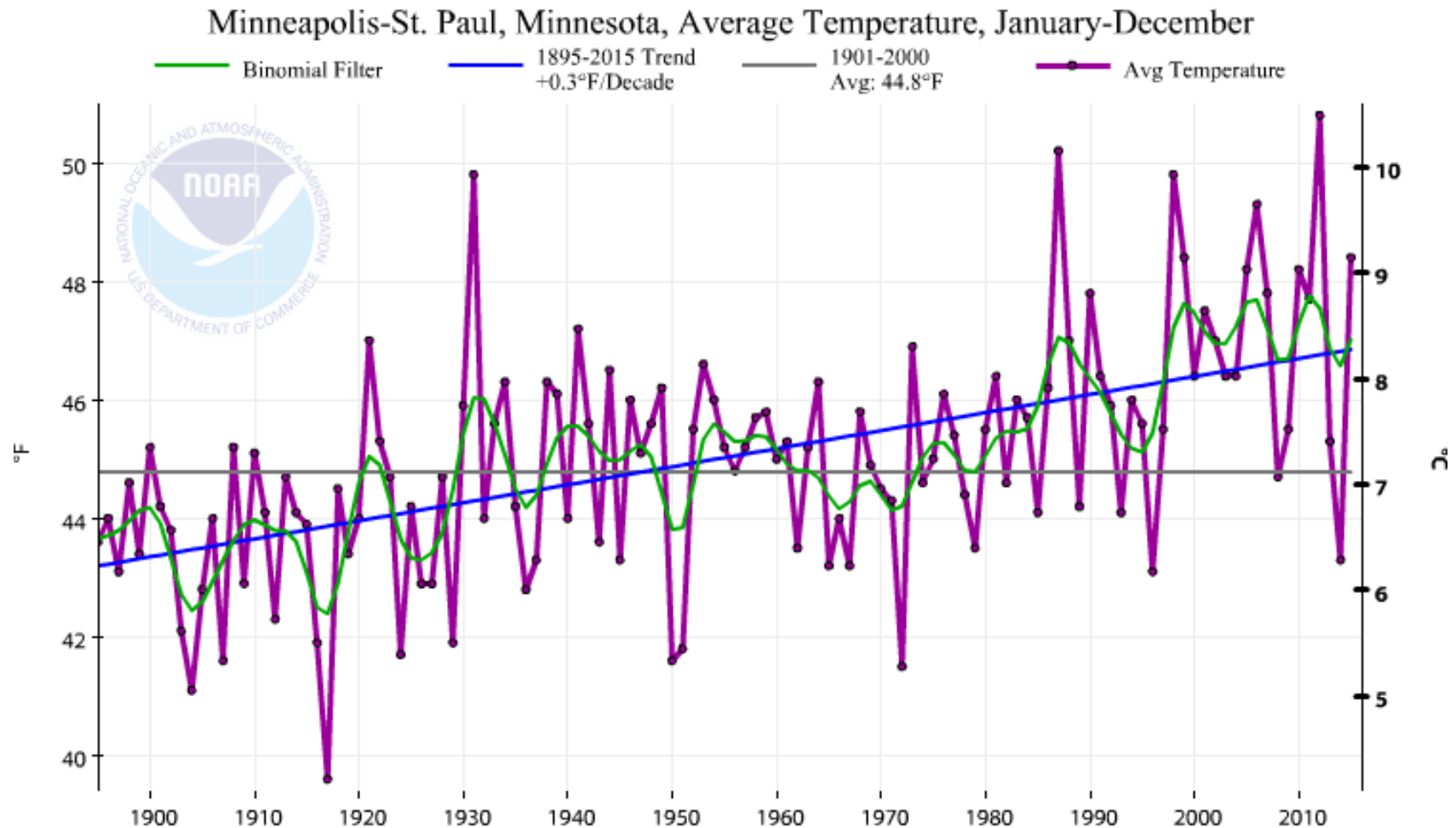
**Disparity in the pace of climate change
relative to temperature**

Minnesota Mean Annual Temperature Trends



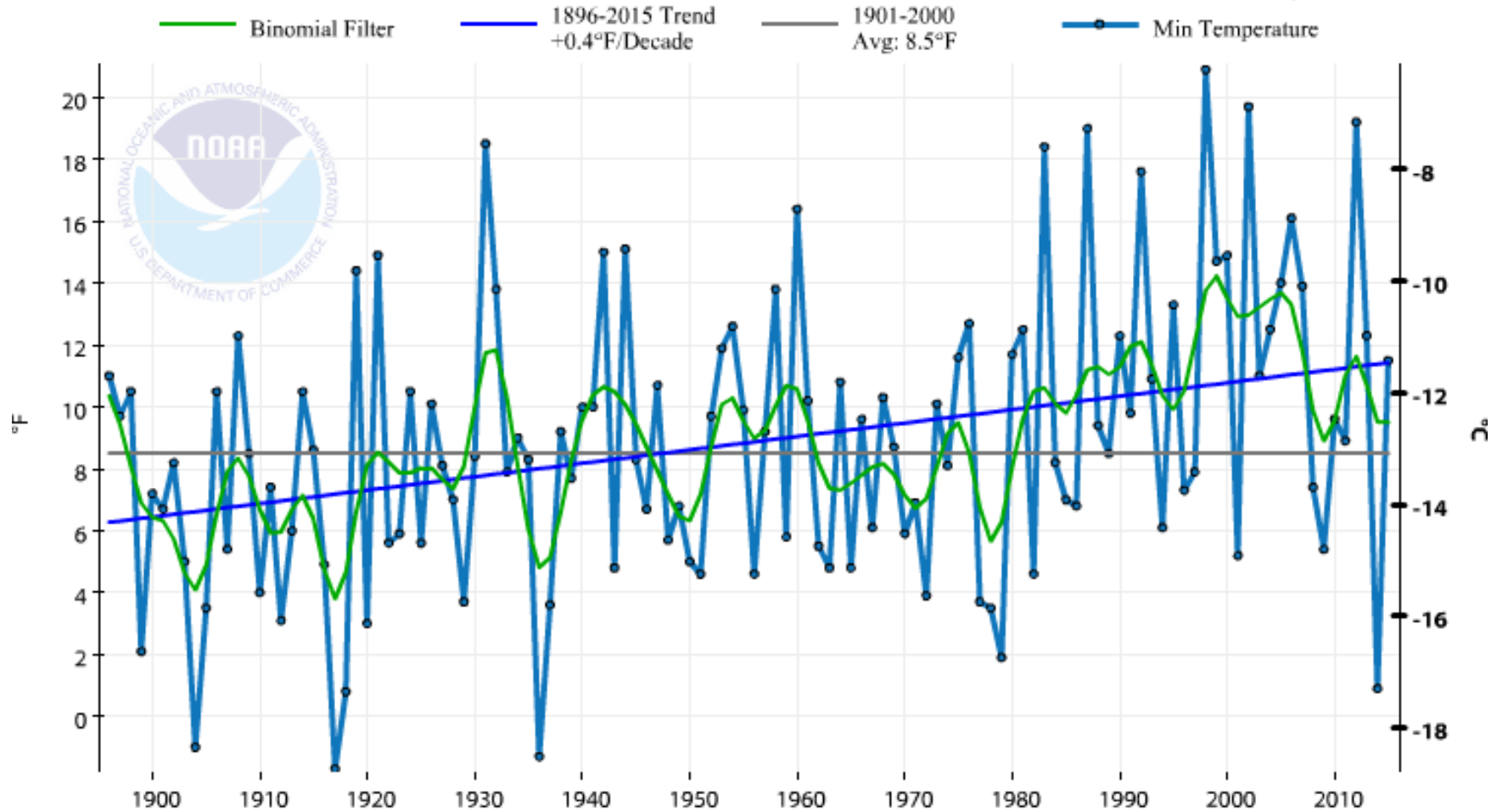
Temp trend is upward and more frequently above the 90th percentile, pace is 2°F per century.

Twin Cities Mean Annual Temperature Trends



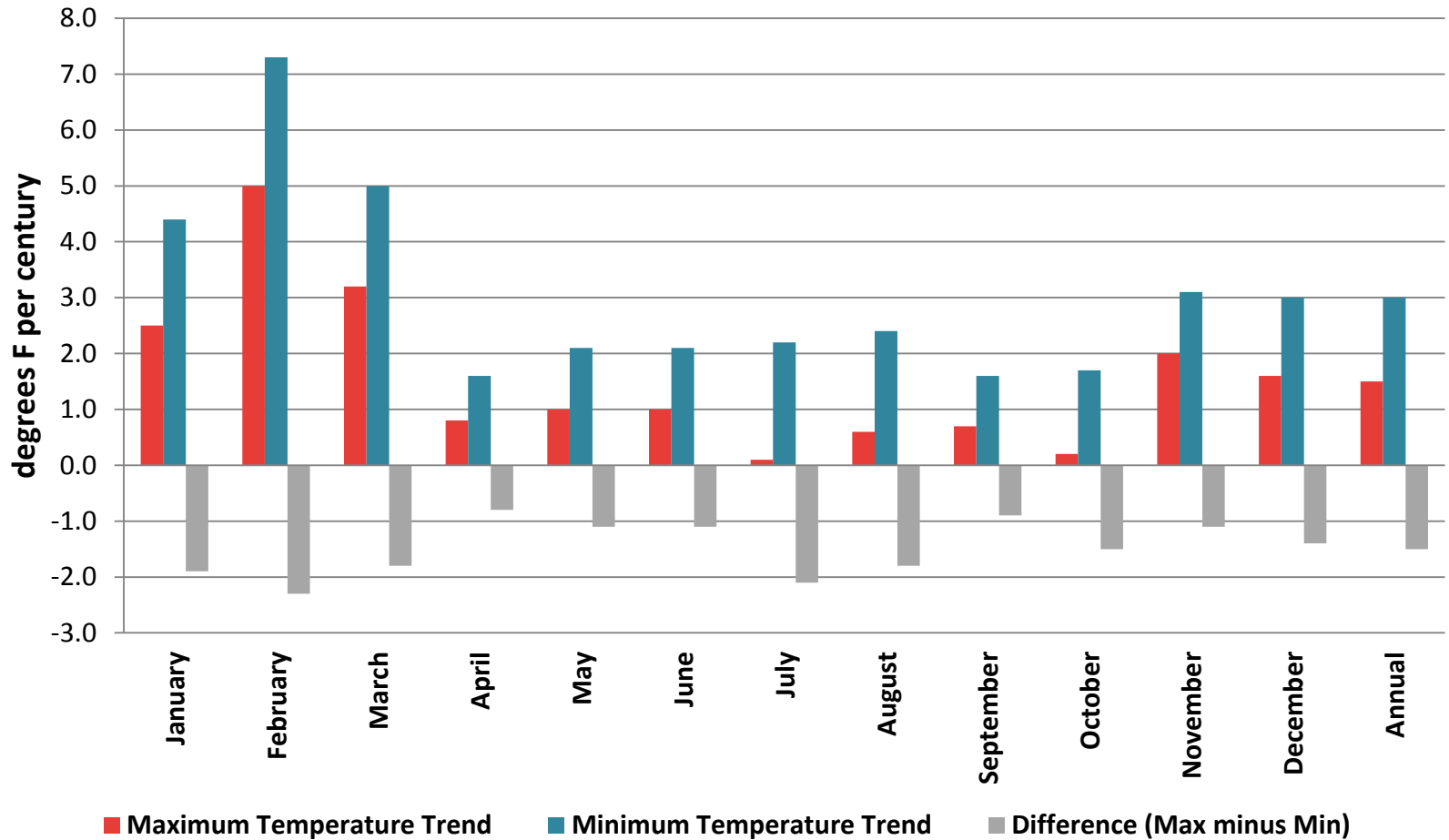
Temp trend is upward and more frequently above the 80th percentile, pace is 3°F per century.

Minneapolis-St. Paul, Minnesota, Minimum Temperature, December-February



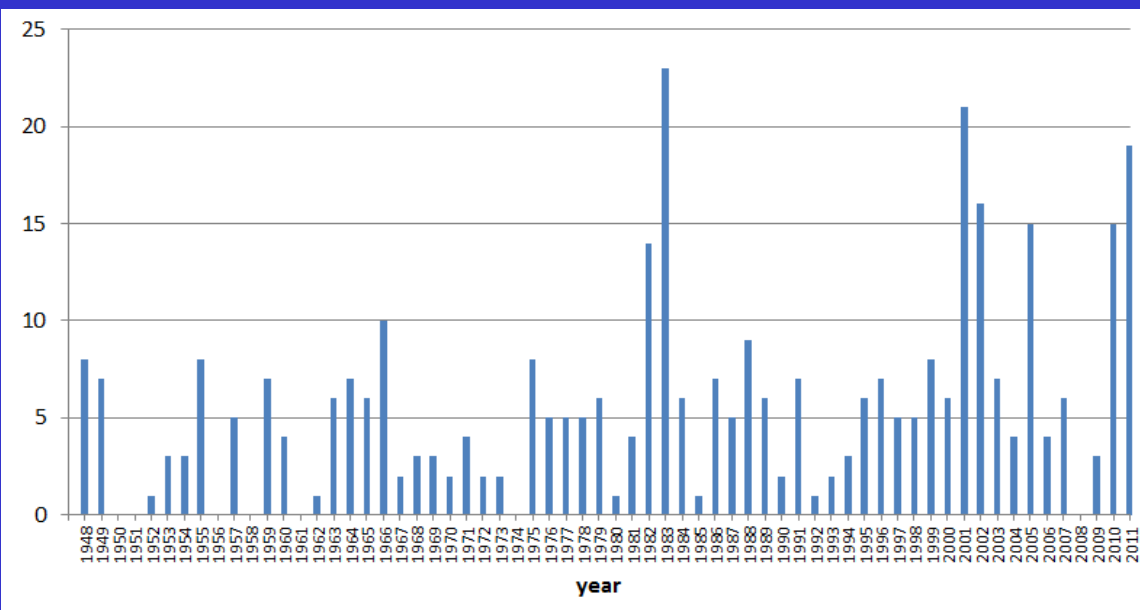
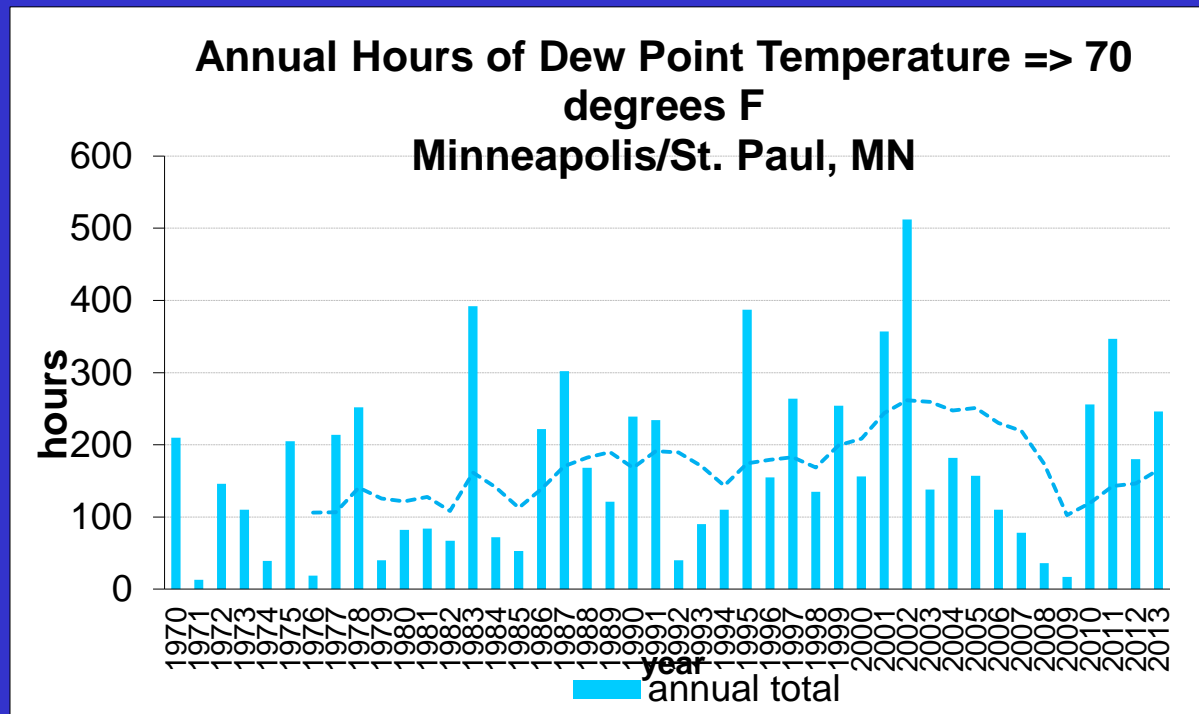
**Change in average winter minimum temperature is 4°F per century
in the Twin Cities climate record**

Minnesota State-Averaged Temperature Trends 1895-2013



Trend in dewpoints of 70 F or higher in the Twin Cities

Latitude 45 degrees

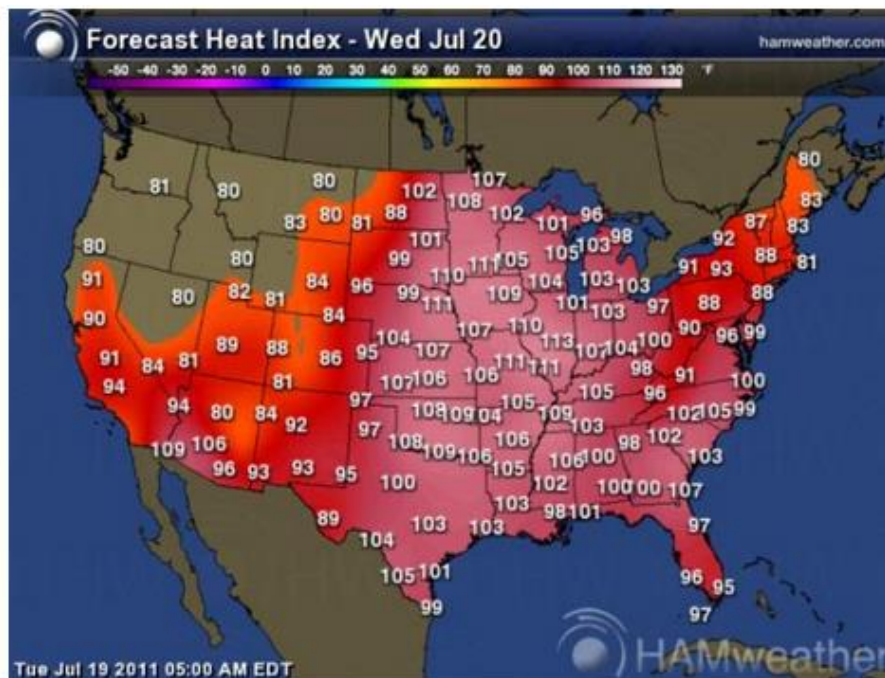


Hours with dewpoints of
70 degrees F or higher
at Voyageurs National
Park

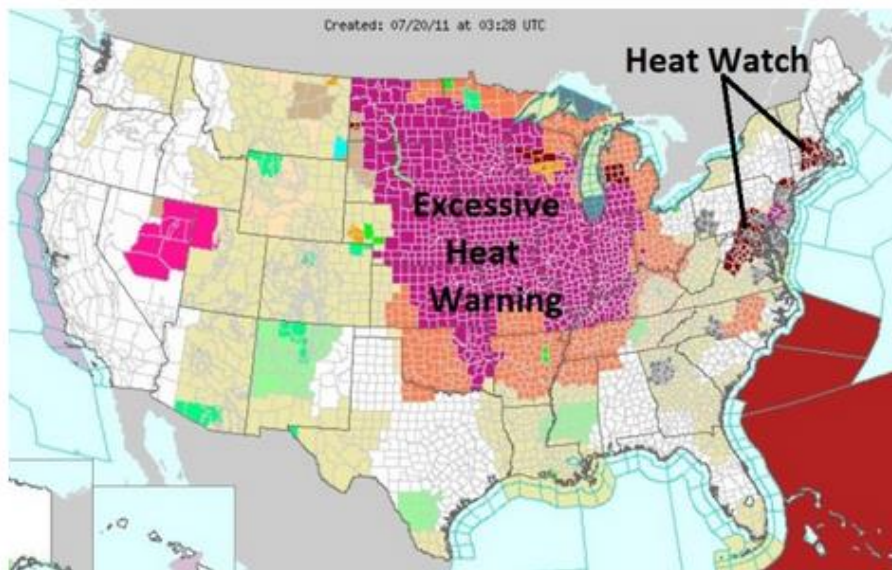
Latitude 48.5 degrees

Frequencies of tropical-like dew points (70 F or higher) and associated Heat Index values for the Twin Cities since 1945

Year	Hours with DP of 70 F or greater	Range of Heat Index Values (F)
1947	256	99 - 112
1949	303	98 - 112
1955	345	98 - 113
1957	243	98 - 112
1959	317	99 - 113
1960	259	98 - 112
1978	252	99 - 114
1983	392	102 - 110
1987	302	98 - 104
1995	387	98 - 116
1997	264	98 - 113
1999	254	98 - 116
2001	357	98 - 110
2002	512	98 - 109
2010	256	98 - 111
2011	347	98 - 118 (*134)
2013	248	99 - 105



The Great Heatwave of '11. Heat indices will top 100 again today from the Great Plains eastward to the Great Lakes, Ohio Valley and southeastern USA, gripping the eastern 2/3rds of America.



July 19-20, 2011 Heat Wave

Heat Index:

112°F Faribault

114°F Mankato

114°F New Ulm

114°F Waseca

117°F Owatonna

118°F Red Wing

119°F Twin Cities

110°F Albert Lea

114°F St James

114°F Fairmount

121°F Austin

134°F Moorhead

Consequences of Warmer Temperatures

Change in depth and duration of soil and lake freezing

Change in survival rates of insect pests, parasites, plant pathogens, and soil microbes

Reduced Heating Degree Days (HDD), increased Cooling Degree Days (CDD)

Increased annual number of freeze/thaw cycles

Change in Plant Hardiness Zones

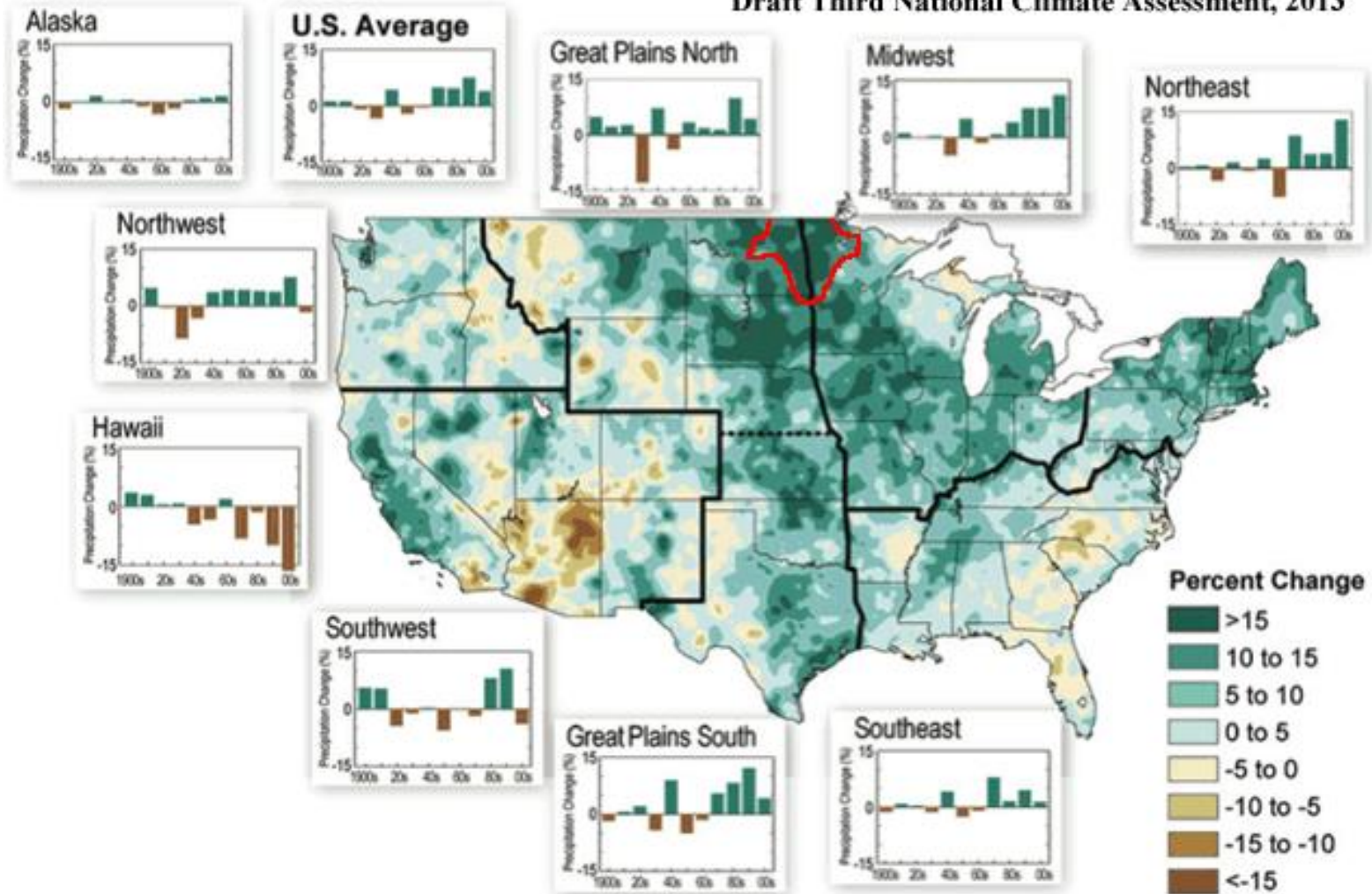
Longer growing seasons

Change in exposure times to mold and allergens

More use of air conditioning, exposure to Heat Waves

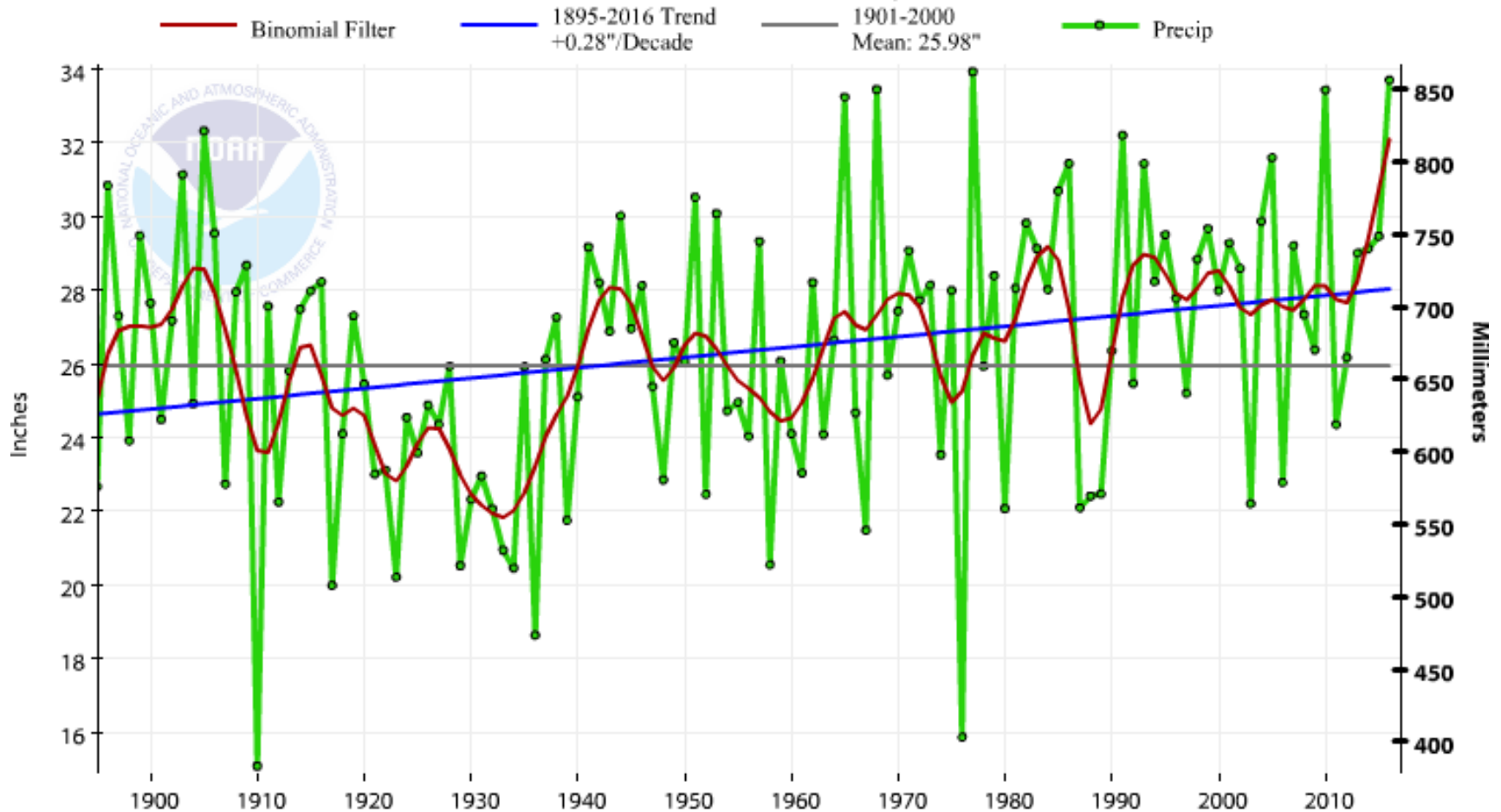
Observed U.S. Precipitation Change, 1991-2011 vs. 1901-1960 Average

Draft Third National Climate Assessment, 2013

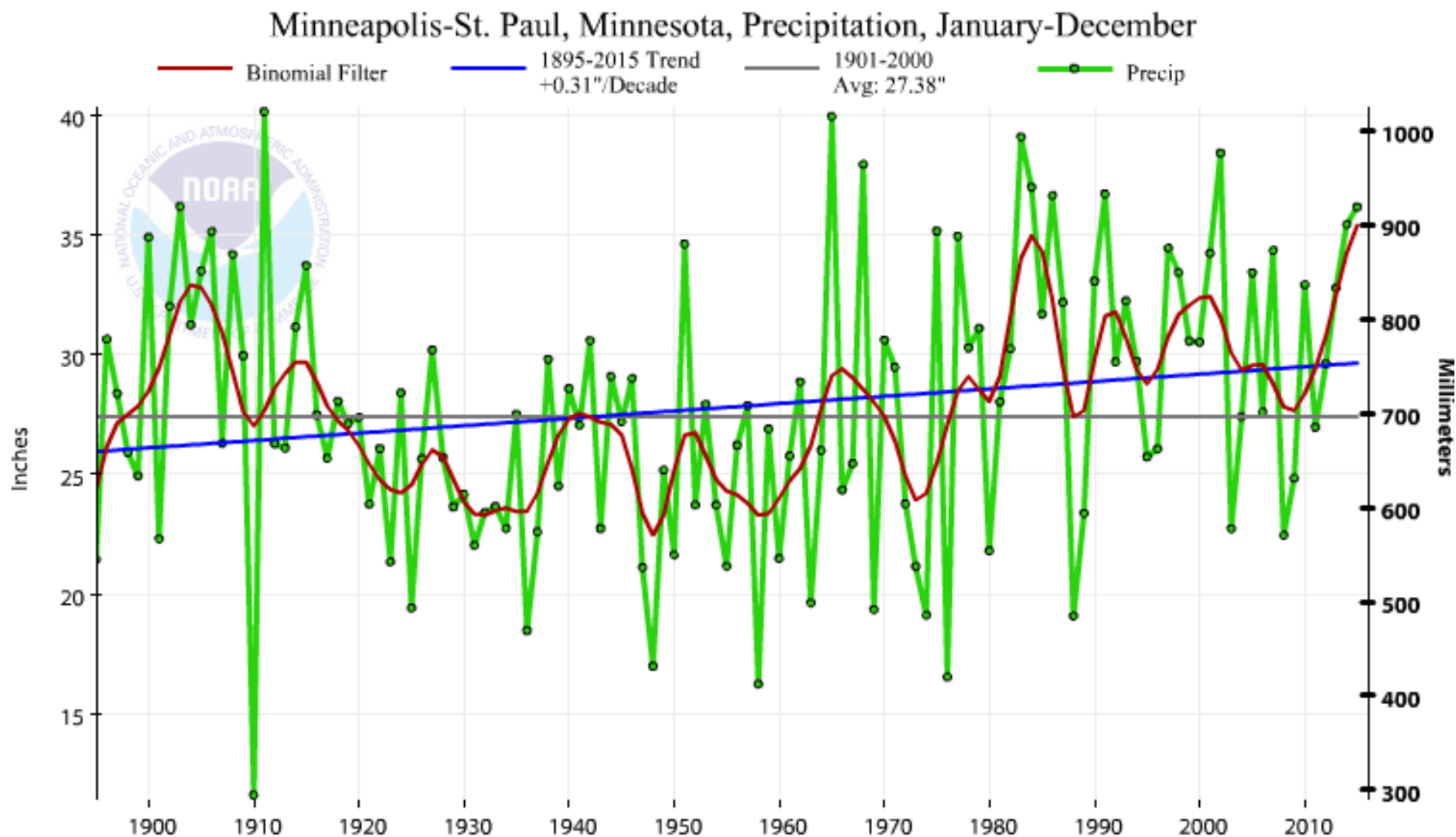


Geographic Disparity in Precipitation Change-IPCC 2013

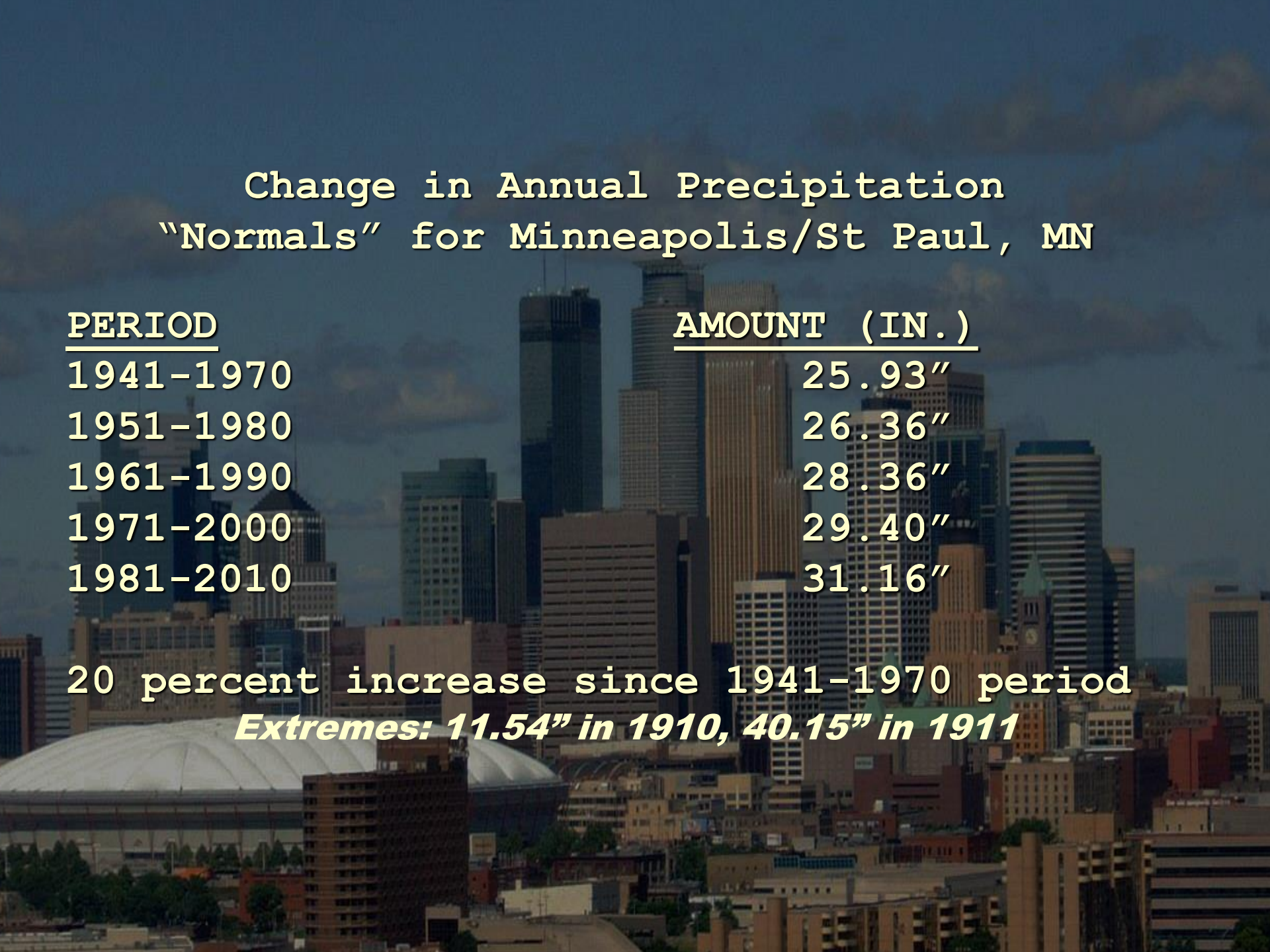
Minnesota, Precipitation, January-December



Trend in annual precipitation for MN



Trend in annual precipitation for Twin Cities

A background image of the Minneapolis skyline, featuring several tall skyscrapers and a large stadium with a white dome in the foreground. The sky is a deep blue with some light clouds.

Change in Annual Precipitation "Normals" for Minneapolis/St Paul, MN

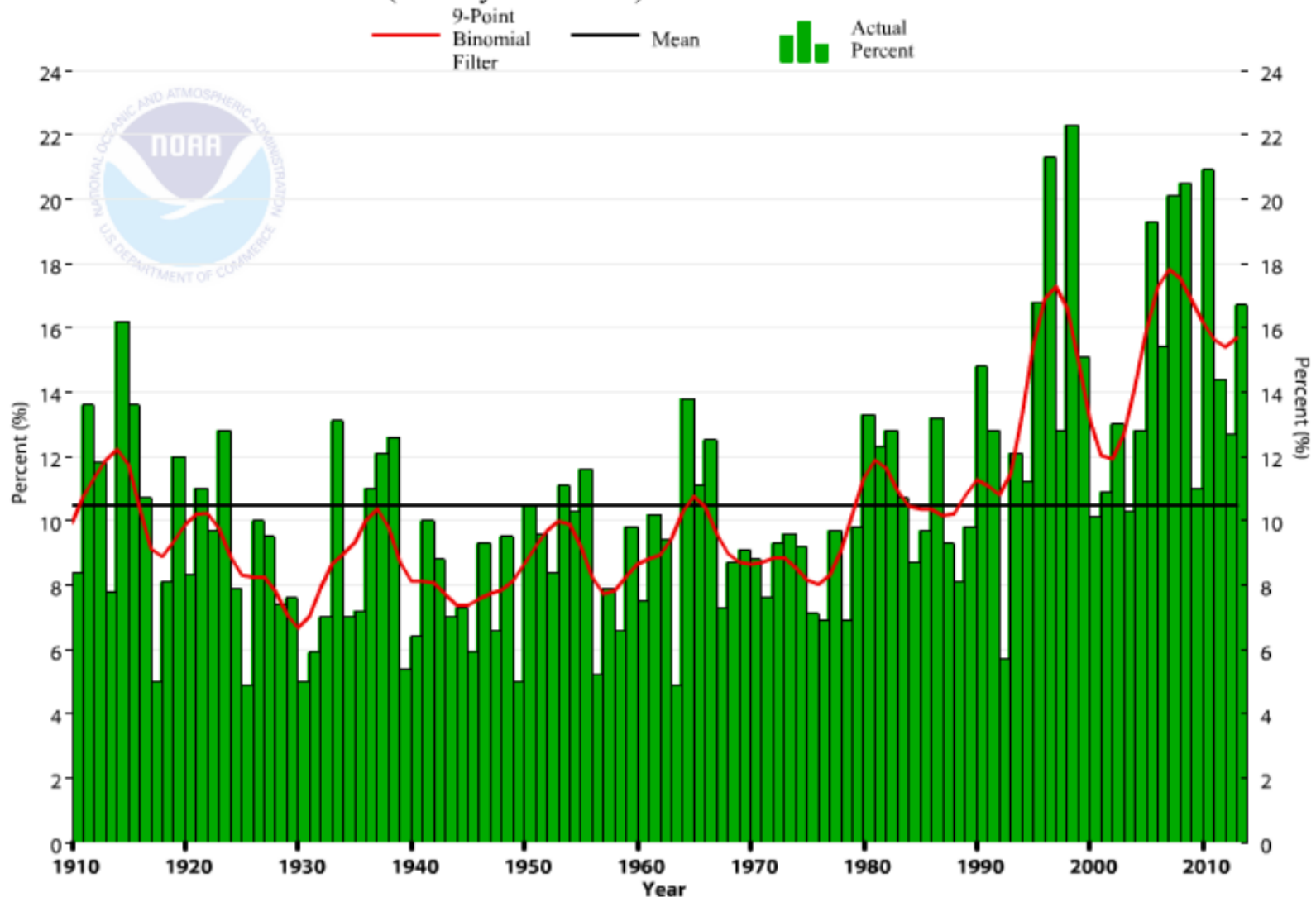
<u>PERIOD</u>	<u>AMOUNT (IN.)</u>
1941-1970	25.93"
1951-1980	26.36"
1961-1990	28.36"
1971-2000	29.40"
1981-2010	31.16"

20 percent increase since 1941-1970 period

Extremes: 11.54" in 1910, 40.15" in 1911

National Heavy Precipitation Changes (www.ncdc.noaa.gov/extremes/cei)

Contiguous U.S. Extremes in 1-Day Precipitation (Step 4*)
Annual (January-December) 1910-2013



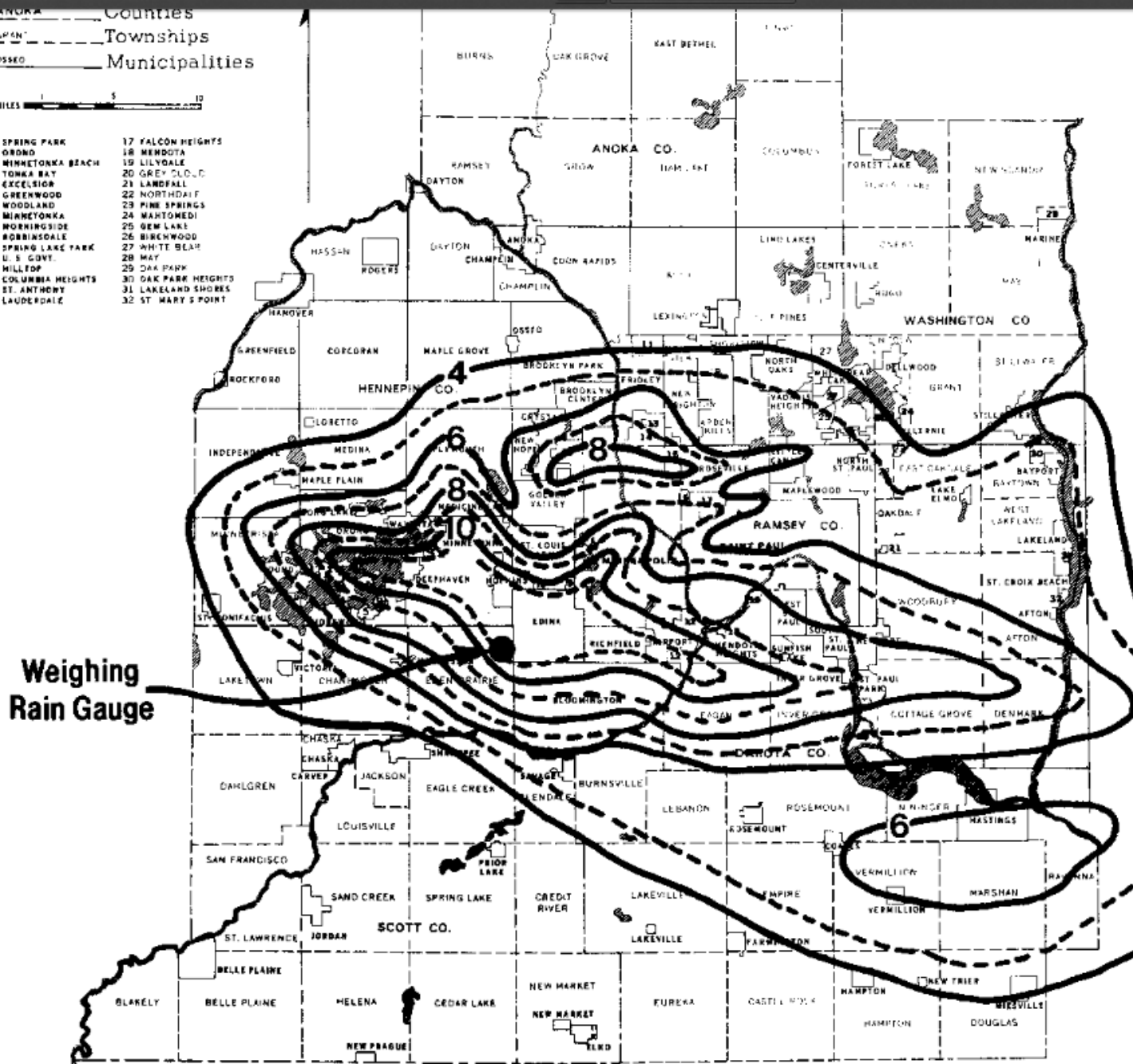
ANOKA --- Counties
 SPAN --- Townships
 OSSEO --- Municipalities

MILES 1 5 10

- | | |
|---------------------|---------------------|
| 1 SPRING PARK | 17 FALCON HEIGHTS |
| 2 GROND | 18 NEWOTA |
| 3 MINNETONKA BEACH | 19 LILYDALE |
| 4 TONKA BAY | 20 GREY CLOUD |
| 5 EXCELSIOR | 21 LANDFALL |
| 6 GREENWOOD | 22 NORTHDALF |
| 7 WOODLAND | 23 PINE SPRINGS |
| 8 MINNETONKA | 24 WARTOMEDI |
| 9 WORKINGSIDE | 25 GEM LAKE |
| 10 ROBBINSDALE | 26 BIRCHWOOD |
| 11 SPRING LAKE PARK | 27 WHITE BLAIR |
| 12 U. S. GOVT. | 28 MAY |
| 13 HILLTOP | 29 OAK PARK |
| 14 COLUMBIA HEIGHTS | 30 OAK PARK HEIGHTS |
| 15 ST. ANTHONY | 31 LAKELAND SHORES |
| 16 LAUDERDALE | 32 ST. MARY'S POINT |

Weighing
Rain Gauge

**Worst flash flood
 in Twin Cities
 history
 Delivered 10
 inches of rain in
 6 hours**





**July 23-24, 1987 in the Twin Cities
10" in 6 hours, and 17.90" for the month**



Observations – Minnesota Trends

Minnesota Mega-rain Events

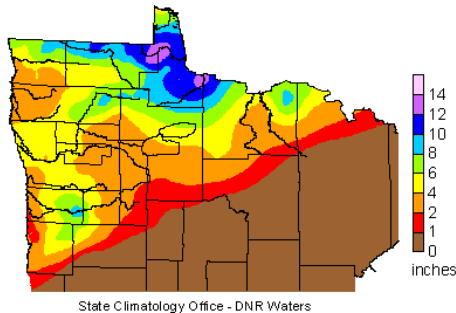
August 6, 1866, Southern Minnesota
July 17-19 1867, Central Minnesota
July 20-22, 1909, Northern Minnesota
September 9-10, 1947 Iron Range
July 21-22, 1972, Grand Daddy Flash Flood
June 28-29, 1975, Northwest Minnesota
July 23-24, 1987, Twin Cities Superstorm
June 9-10, 2002, Northern Minnesota
September 14-15, 2004 Southern Minnesota
August 18-20, 2007, Southern Minnesota
September 22-23, 2010 Southern Minnesota
June 19-20, 2012, Northeast Minnesota
July 11-12, 2016 central and east-central Minnesota
August 10-11, 2016 west-central and southeastern Minnesota

****Defined as 6" or greater rains cover at least 1000 square miles and a peak amount of 8" or greater***

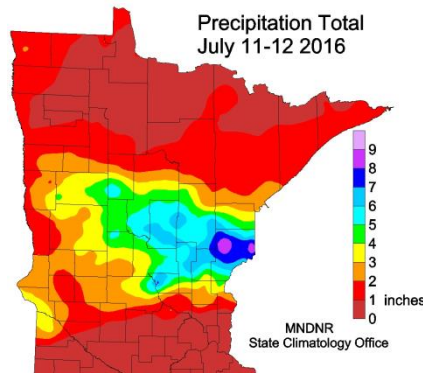
Shift in Precipitation Recurrence Intervals

Mega Rains since 2002

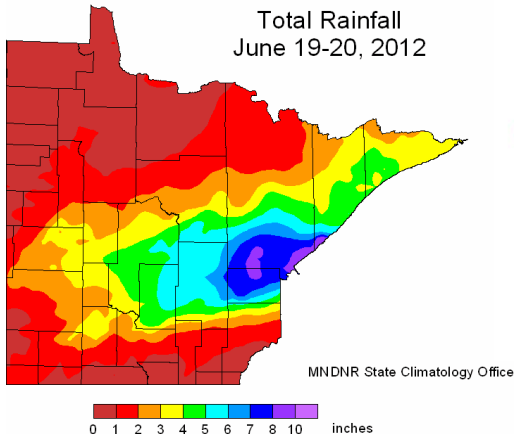
Rainfall Totals - June 9 and 10, 2002



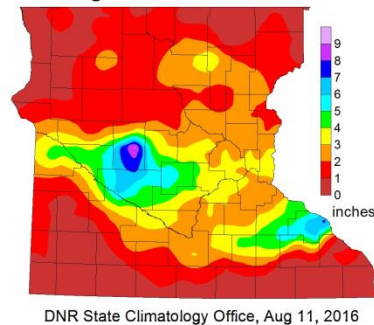
Precipitation Total
July 11-12 2016



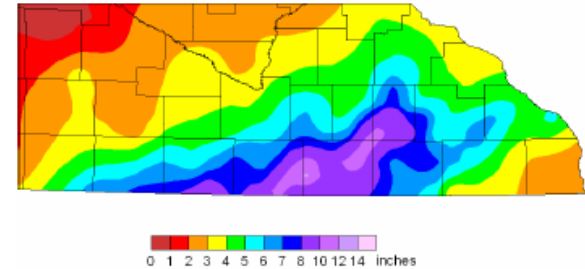
Total Rainfall
June 19-20, 2012



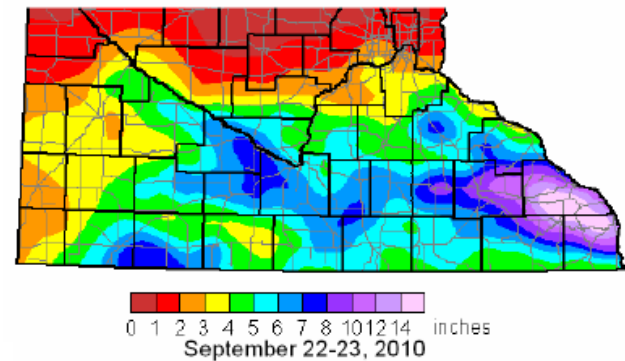
Precipitation Total
August 10-11 2016



'1000-yr (approx.) events' in Southern Minnesota in the last decade.
September 14-15, 2004



August 18 through August 20 (8:00 AM CDT), 2007



'by-eye' estimate of the total area covered by 10" of rain over the 7 years of 2004-2010 appears to be near 1400 sq. mi. or about 200 sq. mi per year. Given that the area of the southern 3 layers of counties looks to be approximately 0000 sq. mi. the areal fraction of the southern three counties covered by 10" per year appears to be approximately /100; i.e. at the rate of coverage for the last 7 years an area equal to the whole southern three county area could be covered in about 100 years.

Consequences of Changes in Precipitation Quantity and Character

**Altered irrigation, tile drainage, runoff,
sediment, and shoreline management**

Farm field and watershed buffer strips

Change in storm sewer design

More emphasis on erosion control

Mitigation of flooding potential

Impact on insurance risk and claims